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LAKE WAKATIPU, NEW ZEALAND.

BY I. C. RUSSELL.

LAKE Wakatipu is remarkable not only for the grandeur of its scenery, which some travelers assert is equal to that of Switzerland, but also for the many interesting features in its physical geology.

Lake Wakatipu is situated about a hundred miles from the southern end of the South Island of New Zealand, among the picturesque mountains of the Southern Alps. Its æsthetic features we will not attempt to describe; a conception of its varying scenes, some of which are as wild and grand as others are soft and beautiful, can be conveyed only by the brush of the artist; we endeavor merely to tell the story of their origin.

The lake is of a sigmoidal shape, about seventy miles long, and from one to three broad. Its waters, which are very clear and cold, have been sounded to the extraordinary depth of *fourteen hundred feet.* The surface of the lake being about one thousand feet above the sea, its bottom, therefore, is four hundred feet lower than the surface of the ocean. On either side of the lake, and thoughout its whole extent, the mountains rise in a continuous series of very rugged peaks to a height of from five thousand to seven thousand five hundred feet, while Mt. Earnslaw, which forms the head of the valley, attains an elevation of 9165 feet, its top white with perpetual snow, and its sides scored by descending glaciers.

The valley of Lake Wakatipu extends southward beyond the foot of the lake for a distance of fifty or sixty miles, and gradually spreads out into the low, level country which forms the province of Southland. As the physical features of the lower portion of the valley are not essentially different from those of the immediate shores of the lake, we are forced to consider them

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as having a common origin, and being but portions of the same valley, the upper part of which is filled with fourteen hundred feet of water, and the lower portion by an unknown depth of worn and rounded shingle. The rocks in which the valley is formed are, for the most part, clay slates and gold-bearing mica schists, which are very much curved and twisted, and in many places green with chlorite.

When we look for the causes, the working power that has produced these grand results, the mind becomes awestruck by the magnitude of the forces which have formed not only the grand valley, but the very mountains in which it exists.

What pictures pass before us when we follow in rapid review the great changes that have resulted in the formation of these rugged mountains, gray and scored as they are by time. We see the sediments which for ages have slowly accumulated at the bottom of the sea, and formed the mud and ooze of ancient oceans, by the action of heat and great pressure hardened and crystallized into rock, and then slowly upheaved by the mysterious volcanic forces into lofty mountain chains whose snowy peaks gleam above the clouds, only to be slowly removed, to have great valleys opened in their sides, and their most solid rocks worn away and carried down particle by particle to be spread out once more at the bottom of the sea. If we consider these changes, grand as they are, as but a single circle in the great cycle of geological time, we can appreciate to some extent the wonders of the history that is written on the rocks. It is only to the last chapter in this history — the formation of the valley — that we would ask your attention.

Valleys may be considered as owing their origin, primarily, to one of three causes: (1.) They are formed by a folding of the rocks, thus forming depressions, the sides of which slope inwards towards the axis, hence designated as *synclinal valleys*. Examples of valleys formed in this way are to be met with wherever stratified rocks have been upheaved, as in the Sierra Nevada, Rocky, and Alleghany Mountains. (2.) Valleys are sometimes formed by the fracturing of the earth's crust by volcanic forces. Valleys of this kind are seldom seen, being confined to regions of great volcanic disturbance. (3.) The kinds of valleys above noticed are usually greatly modified by denudation, which is another great agent in their formation. By denudation we understand the wearing away of rocks not only by wind, frost, and rain, but also by the more powerful action of ice and running water, the operation of which we can see everywhere about us.

As the evidence of a synclinal axis is nowhere apparent in the valley of Lake Wakatipu, we are unable to account for its existence by the upheaval of the mountains on either side of it. We are likewise at a loss to find any indication of the rocks having been rent asunder by volcanic forces. The formation of the valley can be referred only to the third cause, that of denudation, or the slow removal by ice and water of the rock that once filled it to a height greater than that of the mountains which now tower above it.

It may seem strange at first sight that such an immense amount of rock — measured by hundreds of cubic miles in the valley of Lake Wakatipu alone — could have been worn down and transported to distant places by the slow action of ice and water. This difficulty would be removed, could our readers stand with us on one of the many lofty mountains which overlook the lake, and see far up at its head, amid many mountains less grand, the snowy summit of Mt. Earnslaw, on whose sides are blue regions of ice; these are the descending glaciers in which lies the secret of the valley's formation. In those streams of ice that flow down from the snow-fields of Mt. Earnslaw, vast and irresistible as they are, we see but the puny remains of a mighty river of ice that once flowed through the whole valley of Lake Wakatipu, the extent of which was limited only by the ocean, which undermined and floated away its extremity in the form of icebergs, in the same manner that they are formed at the present day on the coast of Greenland. It takes but a glance to convince us that this great ice-river was the engraving tool that, aided by storm and frost, cut in the living rock the picture of wonderful grandeur and beauty that is spread out before us.

The glaciers around Mt. Earnslaw are still at work, as they have been for ages, in extending the valley. The streams that are formed by the melting of the ice are all the year turbid with silt, which is the rock that has been ground fine by the glacier, the flour from the mill, which they deposit in the upper end of the lake. In this manner some six or eight miles of the valley has been filled up to a height of a few feet above the usual level of the lake. We have but to extend the forces now in operation on Mt. Earnslaw to the whole valley of Lake Wakatipu, to have an accurate and satisfactory explanation of its formation.

There is another feature of great interest in the history of this valley, first made known by Captain F. W. Hutton, of Dunedin. On the shore of the lake, about twelve miles above Queenstown, is a limited deposit of tertiary limestone, containing as fossils, *Ostrea Wullerstorfii*, *Cucullœa alta*, *C. Worthingtoni*, *Panopœa plicata*, and many others. The junction of the limestone with the crystalline rocks beneath can be seen but a few feet below the surface of the lake. The limestone being at the present level of the water, the valley must have been eroded to that depth before the limestone was formed. As its deposition took place beneath the waters of the ocean, the valley was at one time an arm of the sea, and was afterwards upheaved to its present elevation or higher, and the wearing down of the valley continued. We have, therefore, as the sequence of events that resulted in the formation of Lake Wakatipu, the following: —

(1.) The Southern Alps forming a sloping table-land, the highest remaining point of which is Mt. Cook, 13,200 feet above the sea; on this high table-land were deposited immense amounts of ice and snow, brought by the warm, moist winds from the ocean, which formed the glaciers that flowed off in various directions towards the sea. One of these ancient rivers of ice had its source in the region about Mt. Earnslaw, — which, however, was then greatly different from its present form — and flowed over what is now the valley of Lake Wakatipu. This old-time glacier continued its slow motion towards the sea for unknown ages, until it had ground out the solid rock to a depth of five or six thousand feet in vertical thickness, and for over a hundred miles in length.

(2.) The work of this mighty glacier was finally terminated by a sinking of the land, which caused the valley to become an arm of the sea, similar in every respect to the deep, narrow fiords that form such a characteristic feature of the west coast of New Zealand at the present day. What before was an alpine valley filled with hundreds of feet of ice then became the home of huge oysters, and many other forms of marine life, whose remains we now find in the limestone. We know that the sea filled the valley for a long time, since the compact gray limestone that it left behind it was not formed rapidly, as sandstone and conglomerate may be, but the material was first gathered from the waters to form the shells of mollusks and foraminifera, or the hard parts of corals, crinoids, etc., and then these worn down to a fine detritus by the waves and spread out as a calcareous sediment, before the hardening process of rock-making can commence. Together with the limestone are beds of fine shale and masses of conglomerate, composed of both rounded and angular pebbles and containing fossil shells (*Crassatella ampla*) These deposits speak of other although minor changes during the time that the waters of the ocean occupied the valley.

(3.) In the third stage the land is again upheaved to the dignity of a mountain chain, whose lofty summits become covered with vast fields of snow and ice, which, seeking an equilibrium, again flow as a glacier down the valley of Lake Wakatipu. This second extension of the ice-stream down the old valley resulted in the removal not only of most of the limestone that had been deposited, but also of fourteen hundred feet of the crystalline rocks beneath. The limestone on the shore of the lake is thus shown to be an inter-glacial deposit, not by being interstratified with beds of till, but by the existence above and below it of distinct glacier-worn valleys.

These great glaciers of New Zealand, together with the occurrence of erratics and moraines in Natal, South Africa, as described by G. W. Snow,[1] indicate a time of extreme cold in the southern hemisphere, corresponding to the glacial epoch that left its records — in the form of striated rocks, bowlders, and moraines — over the northern hemisphere as far south as the fortieth parallel. The limestone of Lake Wakatipu is similar in position to the inter-glacial lignite beds of Switzerland, as described by Professor Heer, and to the inter-glacial forest-beds of Scotland and America. Geologists will notice, however, the greater age of the limestone of Lake Wakatipu, which, as indicated by its fossils, is Upper Eocene, but whether synchronal with the Eocene of Europe has yet to be determined.

The great extension of these ancient glaciers may also be owing, in part at least, to a greater elevation of the land.

Either condition returning to those rich and promising islands, they would again become wrapped in ice and snow, which would swell the ice-streams from Mt. Earnslaw to their ancient dimensions and re-create those giant glaciers.

The second glacier, like the first, had its period of great extension and then slowly passed away. As its terminus retreated up the valley it left behind it the material it had gathered from the overhanging cliffs along its course, or had torn from the sides of the valley, together with the finer products ground by the bottom of the glacier from the rocks over which it passed. This material now forms the filling of the valley below the lake, and has been worked over, perhaps many times, by streams of water that have left it in many regular lines of terraces along the sides of the valley, which form a striking contrast with the angular crags and rocks that tower above them.

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[1] Quarterly Journal of the Geological Society, xxvii. 540.

At Kingston, which is situated at the southern extremity of the lake, a huge terminal moraine, composed of cyclopean masses of angular rock, has been thrown by the glacier directly across the valley, and now forms the shore of the lake. In this confused mass of rocks we have indisputable evidence that here for a long time stood the terminal face of the glacier, which ended abruptly, as is common with glaciers at the present day, and formed a wall of ice from cliff to cliff. The reason why glaciers end so suddenly, and are thus enabled to form terminal moraines, lies in the fact that they are flowing from higher to lower and consequently warmer regions, and must eventually reach a point where the warmth is sufficient to melt the ice of which they are composed, although in many instances this limit is not attained until the glacier enters the sea. The rocks which form the terminal moraine at Kingston were once the lateral moraines on the surface of the glacier, which, as the stream moved on and was melted away, were carried over its terminal face — just as trees and blocks of ice are carried over Niagara — and were left in the confused mass that we find them.

Some idea of the time required for this truly herculean task of valley-making may be gathered from the fact that the average motion of the Swiss glaciers can be taken at about twelve inches a day, or one mile in fourteen and one half years. At this rate a block of stone falling upon the surface of the glacier of Lake Wakatipu near its source at Mt. Earnslaw, would require more than a thousand years to reach its final resting-place in the terminal moraine at Kingston, which is only midway down the valley. This mighty mill, therefore, were it now in existence, could have made but a single turn since Christ was born at Bethlehem.

As the warmth increased, the glaciers retreated to their present position around the summit of Mt. Earnslaw, leaving the valley dammed up by the moraine at Kingston, and filled by the water formed by the melting of the ice. On the sides of the valley, in many places, huge blocks of stone were scattered, similar to those in the moraine at Kingston. They also conferred the rounded form of *roches moutonnées* on the low hills and knolls along the shores of the lake.

We have, therefore, in the valley of Lake Wakatipu a striking example of the manner in which glaciers are enabled to form lake basins, not only by the blocking up of narrow valleys by the masses of dirt and stones carried down on the surface of the ice, but also through the wearing down of the rocks throughout the upper and middle course of the glacier at the same time that they are protected from waste at the lower end by the formation of a terminal moraine. Such we conceive to be the simplest, although imperfect reading, of the grand history of Lake Wakatipu. Other great changes probably took place, however, the records of which have been erased.

Nearly the same words may be written of many other lakes which fill rock-basins, or are confined by ancient moraines, like many of the "lochs" of Scotland, and the long, beautiful sheets of water in the State of New York, of which Lakes Otsego and Seneca are examples. The glaciers to which these lakes owe their origin belonged to the glacial epoch of geologists, and were far mightier than the one whose footsteps we have traced. The excavation of the great lake basins between the United States and Canada has been traced back to the same great ice age.

Not only are we allowed to read the past history of this interesting lake, but we may also look beyond the veil that obscures its future. As the combined action of ice and water have been the instruments for its formation, so are they also working its destruction. After the formation of the moraine at Kingston the waters sought a new outlet from the valley over the falls of the Kawarau, which are constantly being worn away by the action of the water, thus tending to drain the lake to a lower level, as we see by the terraces along its shores that it has been already lowered. While the outlet is every moment becoming deeper, the streams that flow from the foot of the glaciers, together with every little rill and rivulet that is born among the mountains, is continually bringing down its burden of sediment, however small, which is deposited in the lake, and does its share towards filling the valley. If this process seems very slow, or inadequate to accomplish so great a work, we must remember that the operations of nature, unlike those of man, are not crowded into a brief life-time, but continue on through ages. The very glacier that cut this magnificent valley to the depth of a mile and a half in the solid rock, was formed of the little vesicles of mist that were wafted by the wind against the cold mountain-tops, which caused them to crystallize and accumulate on the summits as snow and ice.

The present conditions continuing, where now the deep sea-blue waters of the lake are flushed with the tints of sunset, a rich valley will one day become the home of industry, and its green fields will be animated with the flocks of the husbandman.

A COSMOPOLITAN BUTTERFLY. I. ITS BIRTHPLACE.

BY SAMUEL H. SCUDDER.

THERE is but one butterfly whose range is so extended as to merit the name of cosmopolitan ; it is the Painted Lady or *Vanessa cardui.* With the exception of the arctic regions and South America, it is distributed over the entire extent of every continent. Australia and New Zealand produce a race peculiar to themselves, while the other large islands south of Asia possess the normal type, which is also found upon small islands lying off the western borders of the Old World, the Azores, Canaries, Madeira, and St. Helena. On the other hand, it has not been discovered upon the small islands off the American coast, such as Guadalupe, the Revillagegidos, and Galapagos on the western side, or the Bahamas and Bermudas on the eastern ; neither does it occur in any of the Antilles, excepting Cuba, and there but rarely.[1] It is reported, however, from islands lying in the middle of the Pacific Ocean, such as the Hawaiian group and Tahiti, but its actual occurrence there is at least doubtful.[2]

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[1] Cramer gives it, but probably by mistake, from Jamaica.

[2] The improbability of the occurrence of this insect upon islands lying in the middle of the Pacific Ocean has led me to look carefully into the origin of this general belief. The sole authority for Tahiti is Boisduval, who remarked forty years ago (Nouv. Ann. Mus. Nat. Hist., ii. 191) that he possessed specimens from Tahiti, Brazil, Cayenne, etc.; but it should be noticed that *V. cardui* is not now recognized from Brazil and Cayenne, and that Dr. Boisduval is not considered too careful in his geographical statements ; moreover, Mr. A. G. Butler does not mention it in his List of the Diurnal Lepidoptera of the South Sea Islands (Proc. Zoöl. Soc. Lond., 1874, 274 seq.), and Dr. C. Pickering, the naturalist of Wilkes' Exploring Expedition, tells me that it was unknown on Tahiti in 1839.

The single citation of the Hawaiian Islands will be found in the first list of the British Museum Butterflies, where (p. 79) Mr. Doubleday credits four specimens to those islands, two brought by Captain Byron and two by Captain Beechey. I am informed by Mr. Butler that there is now only one specimen in the museum from the "Sandwich Islands," and the reference upon the ticket is to the oldest manuscript register, not now to be found. Byron and Beechey were at the islands in 1825–27. Mr. W. T. Brigham informs me that *V. cardui* was not found by Mr. Mann and himself during a twelvemonth's residence at the islands ten years ago, and I can find no authority for its present existence. Dr. Pickering writes that it was unknown when Wilkes's expedition visited the islands in 1840–41. The Vincennes, to which Dr. Pickering was attached, was at the islands from the end of September to the beginning of April. Byron and Beechey's visits were between the latter part of January